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Effect of Fuel Injection Pressure and Spray Cone Angle in DI Diesel Engine using CONVERGE^{TM} CFD Code

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Abstract

Fuel spray and atomization play a critical role in the performance and emission characteristics of a direct injection diesel engine. In general the higher fuel injection pressure is favourable for better fuel atomization and may have the better combustion characteristics. It also needs to be making sure that the fuel spray should not hit the walls of the cylinder leading to unaccounted losses. The position of spray and its spread in combustion space is depends on the other parameters such as spray cone angle, nozzle location and orientation etc. The present study analyses the performance and emissions of a diesel engine with respect to fuel injection pressure and spray cone angle using a CONVERGE^{TM} CFD code. The simulation results showed that increase in fuel injection pressure increases the performance but at the same time there is a trade-off observed in NOx and soot emissions. The CFD simulations reveal that the Spray cone angle has also a significant effect on the performance and emissions to a certain extent.

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Keywords: CFD, Fuel Injection Pressure, Spray Cone Angle, Emissions.

1. Introduction

Internal combustions are the major source of environmental pollution which affects the human life in hazardous manner. Reducing the emissions such as NO_x and soot from the IC engines is not an easy task, which is to be

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carefully controlled without losing the desired efficiency. The spray behaviour and its orientation plays an important role in reducing emissions while maintain the desired level of performance [1,2]. Many researchers investigated the effect of fuel injection pressure (FIP) on spray atomization increasing the fuel injection pressure leads to decrease in droplet size and increase the spray penetration. The higher fuel injection pressure is also advantageous in terms of evenly distribution of droplets. Spray penetration may cause the problem of wall wetting thereby causes unaccounted losses. The cone angle is illustrated in the fig 2. The average range of the cone angle is 10- 25°. The fuel injection pressure in a standard diesel engine is in the range of 200 to 1700 bar depending on the engine size and type of combustion system employed. The first generation CRDI fuel injector can operate up to 1350 bar average fuel injection pressure. The fuel injection system is used in a direct injection diesel engine to achieve a high degree of atomization and better penetration into the combustion chamber. Higher injection pressure promotes better evaporation and atomization of fuel in a very short time. The fuel injection pressure and spray cone angle are the major parameters which influence the combustion phenomena [2,3,4,5].

2. Simulation model

The CAT 3401 engine is considered for the simulation analysis its dimensions and other parameters are given in the table 1. To reduce the computational time engine sector model was used with the angle subtended by sector is 60 degrees.This model is shown in fig 1 comprises one sixth of the engine total volume.

Table 1.Caterpillar 3401 engine standard specifications. [6]

Bore	137.16 mm
Stroke	165.1 mm
Connecting rod length	263 mm
Engine speed	1600 RPM
Compression Ratio	16
Number of nozzle orifices	6
Start of Injection timing	9° bTDC
Duration of injection	21°
Fuel injected	0.1621 g/cycle

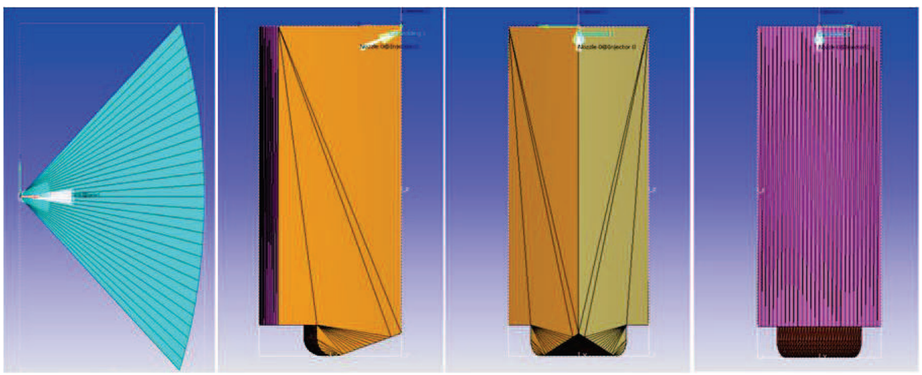

Fig. 1. Sector model of CAT 3401 with top, back, left side and right side views (left to right)

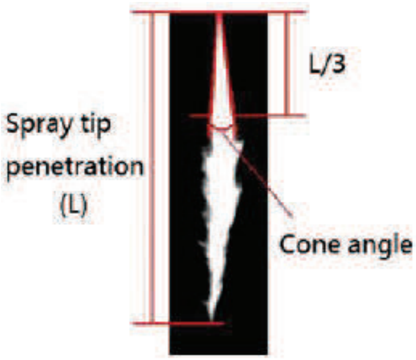

Fig. 2. Illustration of cone angle [2]

3. Results and Discussion

The current section presents the simulation results of different fuel Injection pressures and spray cone angles at constant load, 1600 RPM, 16 compression ratio and SOI 9° bTDC. The products after combustion at 80° aTDC were considered as emissions and their quantity is converted into specific emissions (g/kg fuel) by dividing with mass of the fuel injected.

3.1 Effect of Varying the Fuel Injection Pressure

As the fuel injection pressure increases from 220 to 1400 bar the value of peak pressure increases from 89 to 120 bar and peak temperature goes up from 1535 to 1989 K. This is due to the fact that higher injection pressures reduces the size of fuel droplet and also causes better penetration into the combustion space. Due to this, more surface area of the fuel droplets is interacting with hot in-cylinder air. So, it results in better mixture formation and efficient combustion of the charge.

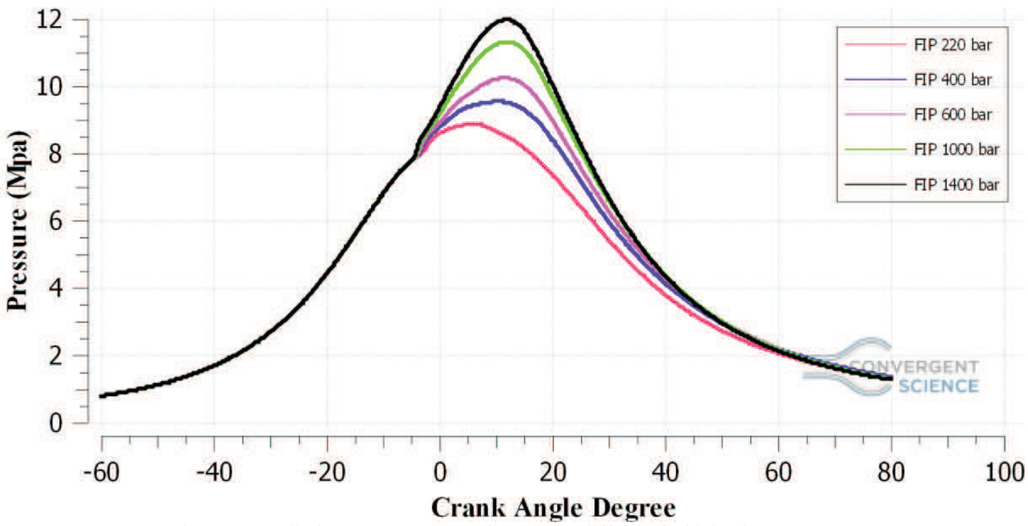

Fig. 3.Avg Cylinder Pressure vs. Crank angle for different fuel injection pressures

Fig. 4 & 5 shows the NOx and soot inside the cylinder with respect to crank angle. There is an increment in NOx emissions as a result of increased FIP. Higher peak temperature value at higher FIP is the reason behind such trend. NOx emission increases from 20 to 74 gm/kg-fuel as FIP is increased from 220 to 1400 bar respectively. As the FIP is increased from 220 to 1400 bar, soot emission comes down because of better combustion at higher FIP. Soot decrease rapidly and were almost zero as FIP is increased from 220 to 1400 bar respectively.

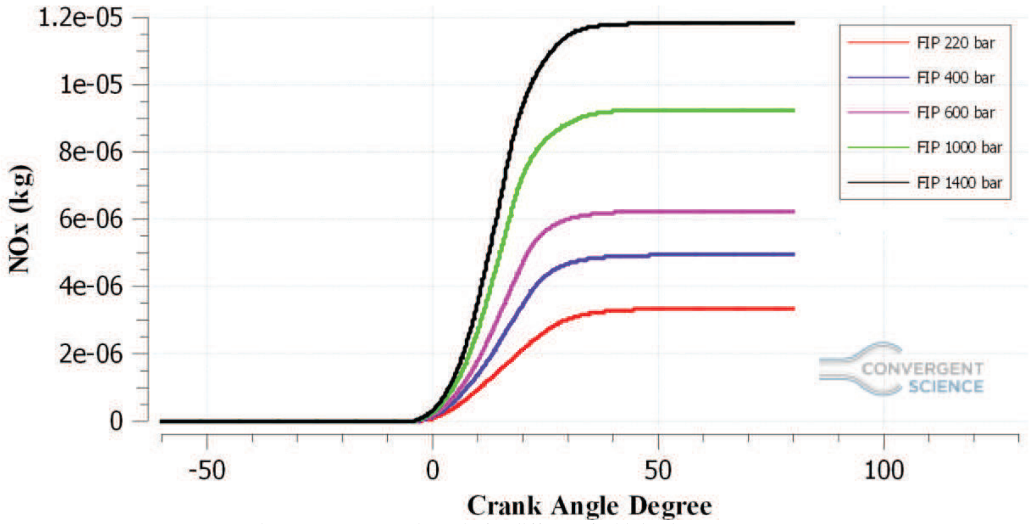

Fig. 4.NOx vs. Crank angle for different fuel injection pressures

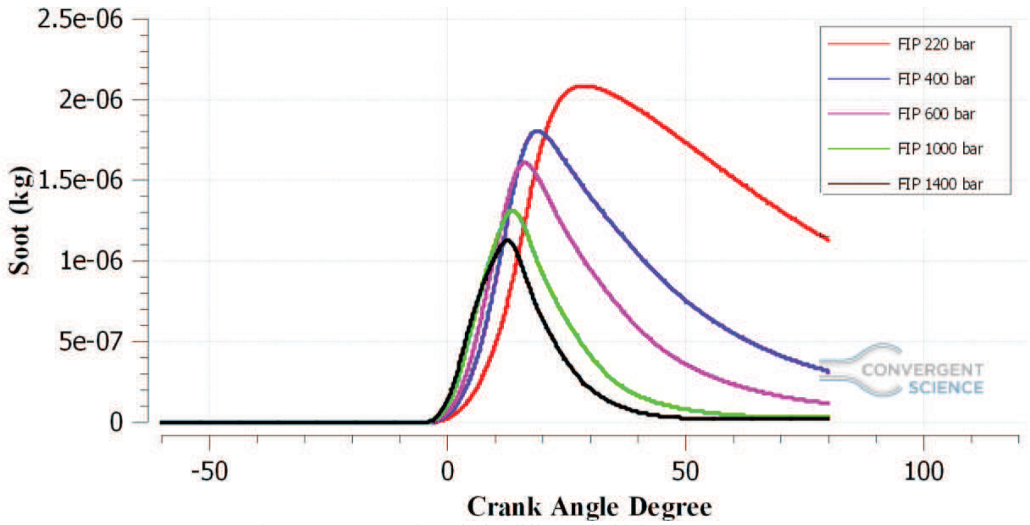

Fig. 5.Soot vs. Crank angle for different fuel injection pressures

3.2 Effect of Varying spray cone angle

The spray cone angle cannot be constant and varied throughout the spray. The numerical experiments were conducted with 3 different averaged spray cone angles 9, 15 and 23. It is observed from the fig 6 that the peak pressures of cone angle 15, 23 were similar in the range of 90 bar. The peak pressure for cone angle 9 is 110 bar which is higher than the 15 and 23. This shows the better performance in terms of higher indicated power for the case cone angle 9. Similarly from the fig 7 and 8 shows the emission characteristics such as NOx and soot. The NOx and soot emissions are similar for the two cases cone angle 15 and 23.The NOx emissions were slightly higher for cone angle 9 whereas the soot emissions are less compared with other two cases.

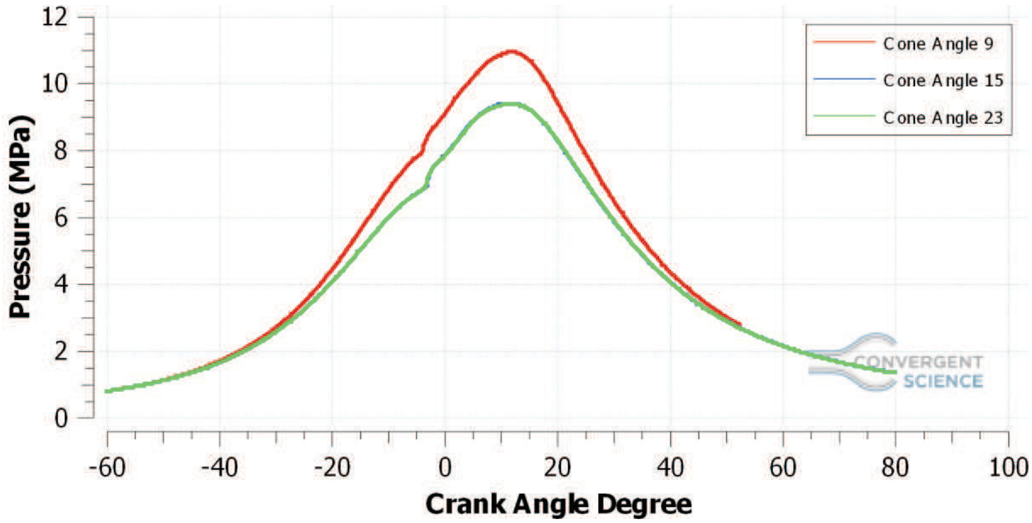

Fig. 6.Avg Cylinder Pressure vs. Crank angle for different spray cone angles

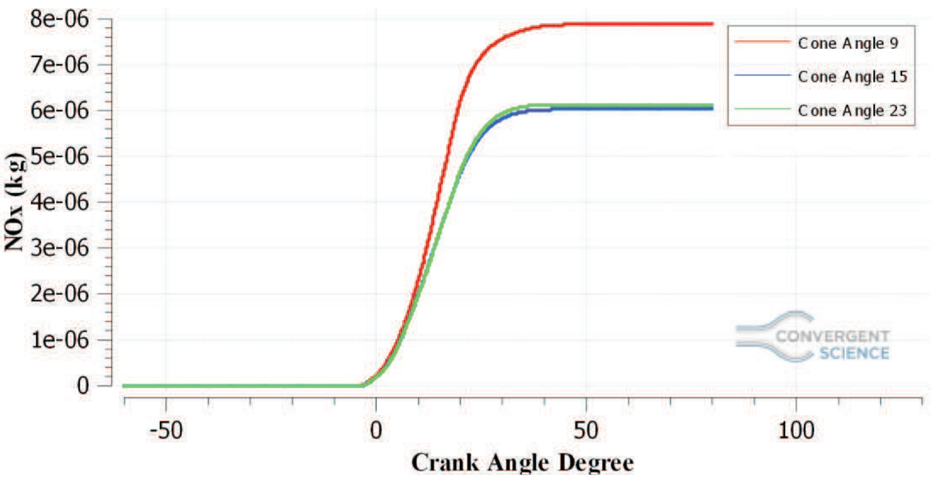

Fig. 7.NO_x vs. Crank angle for different spray cone angles

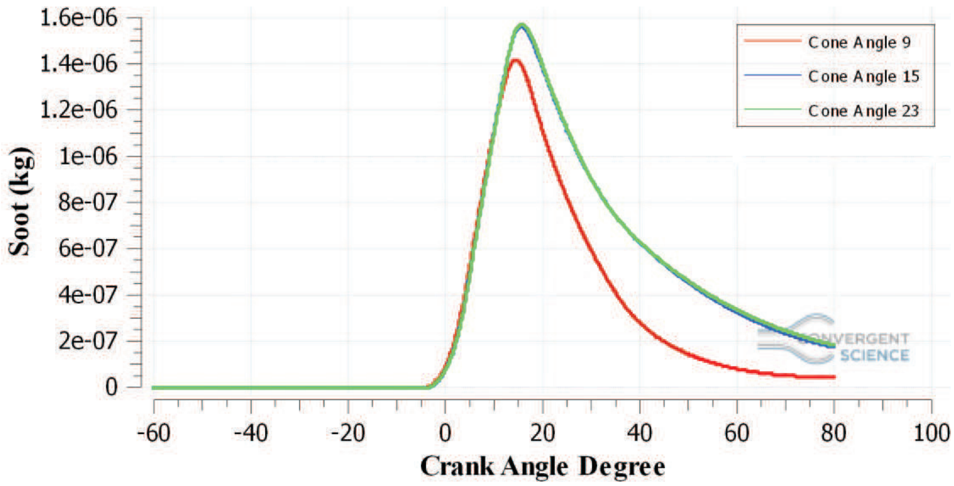

Fig. 8.Soot vs. Crank angle for different spray cone angles

4. Conclusions and future work

- Higher fuel injection pressure is better for smaller droplet size and leads to better combustion
- Narrow spray cone angle are better for the better combustion and performance.
- Among the numerical experiments conducted the optimum spray cone angle was found to be 9° and the optimum fuel injection pressure was 1000 bar.
- In future effect of nozzle diameter, spray orientation will be studied on performance and emissions characteristics

References

[1] Chen, P. C., Wang, W. C., Roberts, W. L., & Fang, T. (2013). Spray and atomization of diesel fuel and its alternatives from a single-hole injector using a common rail fuel injection system. Fuel, 103, 850-861.

[2] Ryu, J., Kim, H., & Lee, K. (2005). A study on the spray structure and evaporation characteristic of common rail type high pressure injector in homogeneous charge compression ignition engine. Fuel, 84(18), 2341-2350.

[3] Kuti, O. A., Zhu, J., Nishida, K., Wang, X., & Huang, Z. (2013). Characterization of spray and combustion processes of biodiesel fuel injected by diesel engine common rail system. Fuel, 104, 838-846.

[4] Flaig, U., Polach, W., & Ziegler, G. (1999). Common Rail System (CR-System) for passenger car DI diesel engines; Experiences with applications for series production projects (No. 1999-01-0191). SAE Technical Paper.

[5] Henein, N. A., Bhattacharyya, A., Schipper, J., Kastury, A., & Bryzik, W. (2006). Effect of injection pressure and swirl motion on diesel engine-out emissions in conventional and advanced combustion regimes (No. 2006-01-0076). SAE Technical Paper.

[6] Aglave R, Riedel U, Warnatz J (2008).Turbulence-chemistry interactions in CFD modelling of diesel engines",Combustion Theory and Modelling,12:2305-25.